TECHNICAL SUPPORT DOCUMENT

YUMA, ARIZONA NATURAL EVENTS ACTION PLAN

FOR

A PM_{10} EXCEEDANCE ON AUGUST 18, 2002

Air Assessment Section
Arizona Department of Environmental Quality

February 17, 2004

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1.0 INTRODUCTION

This technical support document discusses several aspects of PM_{10} in Yuma, particularly the PM_{10} exceedance recorded on August 18, 2002, and the emission sources which contributed to this exceedance. Some background information on the nature of elevated PM_{10} concentrations and rainfall is presented and long-term PM_{10} trends are discussed. A complete inventory of the area's PM_{10} emissions was constructed in 2002 and its highlights will be examined.

Air quality modeling is necessary to determine how much each emission source contributes to a particular PM_{10} concentration. This modeling is fully described in Section 7 of the document.

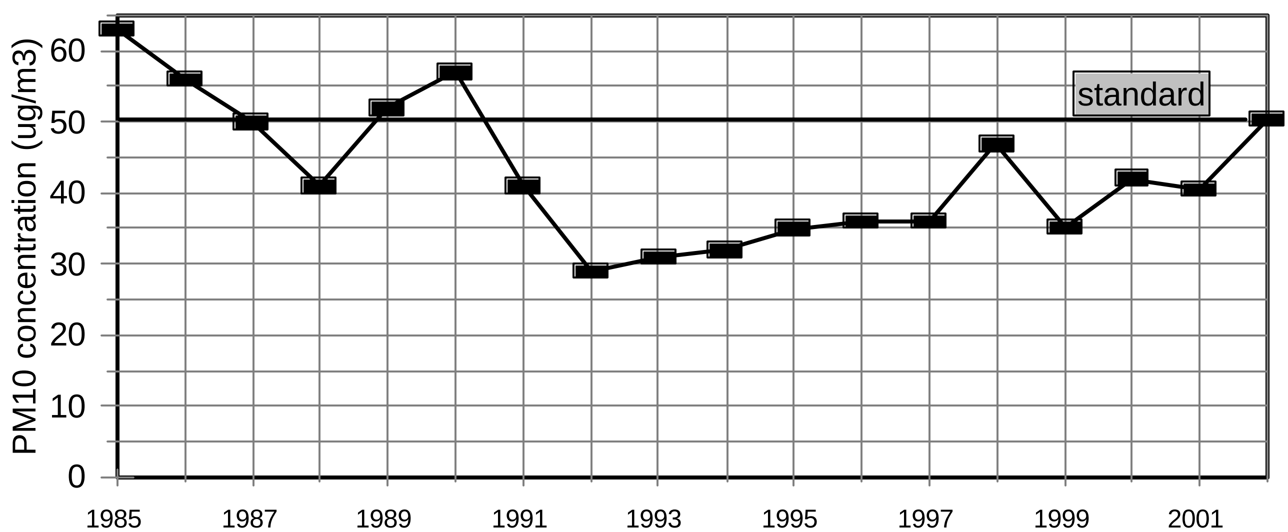
Finally, the emission sources contributing to the exceedance and each one's percentage contribution are discussed in detail.

2.0 PM_{10} TRENDS

ADEQ has operated a PM_{10} monitor at the Yuma Juvenile Center since 1985. The 24-hour averages recorded at this site are taken from midnight to midnight every sixth day, and can be considered broadly representative of the population exposure in the vicinity near the monitor.

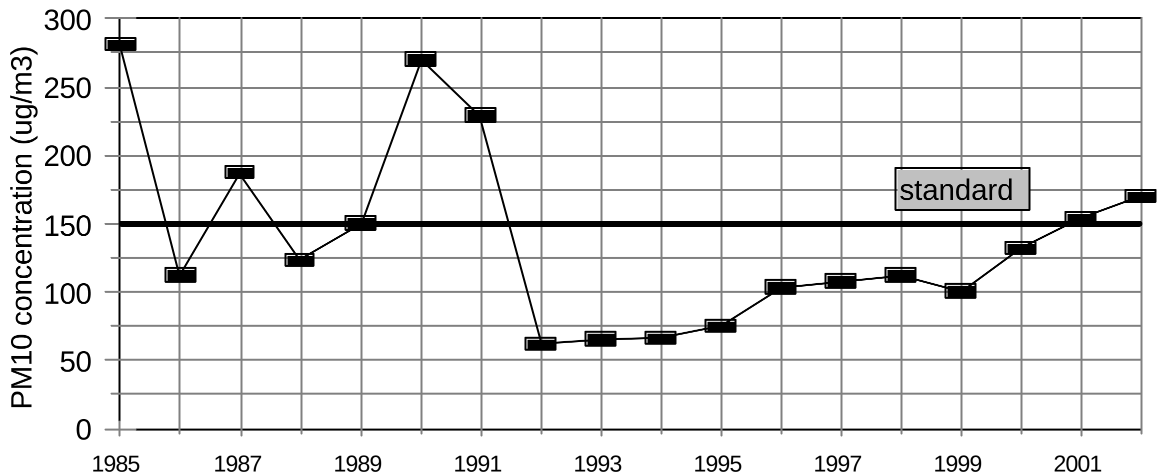
The National Ambient Air Quality Standards (NAAQS) for PM_{10} are 150 $\mu g/m^3$ for the 24-hour average standard and 50 $\mu g/m^3$ for the annual average. The annual average is composed of 60 individual 24-hour averages. Since 1985, the annual average PM_{10} concentration has gone through three phases (Figure 2-1). First, in 1985 through 1990, the values ranged from 40 $\mu g/m^3$ to just above 60 $\mu g/m^3$ and were above the standard for four of these six years. Second, a two-year period of rapid decline took place in 1991 – 1992. Third, since 1993, these annual PM_{10} averages have crept up steadily. This upward trend, towards higher concentrations of PM_{10}, culminated in an annual average of 50.4 $\mu g/m^3$ in 2002.

Figure 2-1. Annual Average PM_{10} concentrations in Yuma, 1985 – 2002



In contrast to the more stable annual averages, the highest PM_{10} 24-hour average recorded in a year is a rather volatile statistic. Two different scenarios can cause high PM_{10} concentrations: the first is high dust emissions close to the monitor coupled with stagnant meteorological conditions; the second is a regional-scale dust storm, such as the one of August 18, 2002. While the maximum 24-hour average concentration is more prone to erratic shifts than the annual average, Figure 2-2 shows that its trend line is remarkably similar to the annual average.

Figure 2-2 Maximum 24-hour PM_{10} concentrations in Yuma, 1985 – 2002



The highest of these concentrations occurred over ten years ago. The trend since 1995, as is the case with the annual average, is upward.

3.0 RELATIONSHIP BETWEEN RAINFALL AND ELEVATED PM_{10}

In the Southwest deserts, all particulate matter monitoring and regulatory programs have to deal with blowing dust. PM_{10} consists mostly of particles of geologic origin. Most of the mass of these particles is in the coarse fraction from 2.5 to 10 microns. This breakdown applies to both windy and calm days. The frequency of rainfall, however, can change the picture somewhat. If many of the highest 24-hour average PM_{10} concentrations are recorded on high-wind days, and if more frequent rainfall reduces the potential for windblown dust, then in a long-term trend, more rain should translate into lower PM_{10} concentrations.

Arizona's definition of an "exceptional event" for PM_{10}, to be discussed in Chapter 5 of this report, takes rainfall into account in two ways. First, the rainfall that occurs during the 60 days preceding the high PM_{10} event is compared with the fourth percentile level. Second, the rainfall from the preceding winter (October – March) is compared with the fourth percentile level. These tests are employed along with wind speeds on the day in question to determine whether the event is exceptional. This two-period approach recognizes that winter precipitation reduces the potential for dust emissions during and after the winter season, as heavier winter rains produce more vegetation in disturbed and undisturbed soils. This heavier vegetative cover lasts longer into the spring, again reducing the potential for dust emissions. On the other side of the relationship, certain dust emissions can increase in the days after rainfall. The re-entrained dust from paved surfaces, for example, can increase after a rain because of the soil that is eroded or tracked, onto road surfaces.

High winds occur in the Southwest deserts in the spring with the passage of dry cold fronts that often occur in April. High winds occur again in the summer, typically July and August, from the development of monsoon thunderstorms. High PM_{10} concentrations, while not exclusively associated with high winds, are recorded during these high-wind seasons. The long-term PM_{10} monitoring record, when viewed against the rainfall record, does not reveal a solid cause-and-effect relationship between rainfall and ambient PM_{10} concentrations. Monthly rainfall statistics for 1991 through 2002 are given in Table 3-1. Figure 3-1 displays the annual rainfall in Yuma for this period, and Figure 3-2 shows the annual average PM_{10} concentrations and the annual maximum 24-hour PM_{10} concentrations. Neither PM_{10} average appears to be consistently responding to rainfall. No matter what the long-term rainfall trend is, in the five critical high-wind months of April through August, slightly over half of the 60 monthly values in 1991 through 2002 are zero. This suggests that in any given year, conditions will be dry often enough to maximize the potential for windblown dust. In extremely dry years, such as 2002, that potential for high PM_{10} concentrations from high winds increases even more.

Table 3-1 Yuma monthly rainfall: 1991 – 2002

(Units are inches)

	1991	1992	1993	1994	1995	1996
Jan	0.13	0.27	1.88	0.02	0.48	0.00
Feb	0.20	0.73	1.13	0.29	0.05	0.10
Mar	0.57	1.38	0.34	0.13	0.26	0.01
Apr	0.00	0.13	0.00	0.00	0.17	0.00
May	0.00	0.27	0.01	0.28	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.20	0.00
Aug	0.01	0.23	0.07	0.06	0.00	0.18
Sep	0.12	0.00	0.02	2.07	0.03	0.02
Oct	0.13	0.00	0.86	0.00	0.00	0.03
Nov	0.06	0.00	1.07	0.01	0.03	0.00
Dec	0.62	1.70	0.00	1.35	0.00	0.00
Total	1.84	4.71	5.38	4.21	1.22	0.34

	1997	1998	1999	2000	2001	2002	Average
Jan	0.00	0.02	0.00	0.00	0.42	0.00	0.27
Feb	0.00	0.89	0.42	0.07	0.69	0.00	0.38
Mar	0.00	0.43	0.00	0.37	1.83	0.01	0.44
Apr	0.00	0.02	1.19	0.00	0.12	0.00	0.14
May	0.00	0.01	0.00	0.00	0.00	0.00	0.05
Jun	0.17	0.00	0.03	0.00	0.00	0.00	0.02
Jul	0.32	0.06	0.36	0.00	0.18	0.00	0.09
Aug	0.00	0.32	0.04	1.15	0.10	0.00	0.18
Sep	5.37	1.84	0.20	0.00	0.00	0.08	0.81
Oct	0.14	0.00	0.00	0.03	0.12	0.09	0.12
Nov	0.00	0.04	0.00	0.00	0.01	0.02	0.10
Dec	1.96	0.19	0.00	0.00	0.01	0.00	0.49
Total	7.96	3.82	2.24	1.62	3.48	0.20	3.08

SOURCE: National Weather Service

Figure 3-1 Yuma annual rainfall: 1991 - 2002

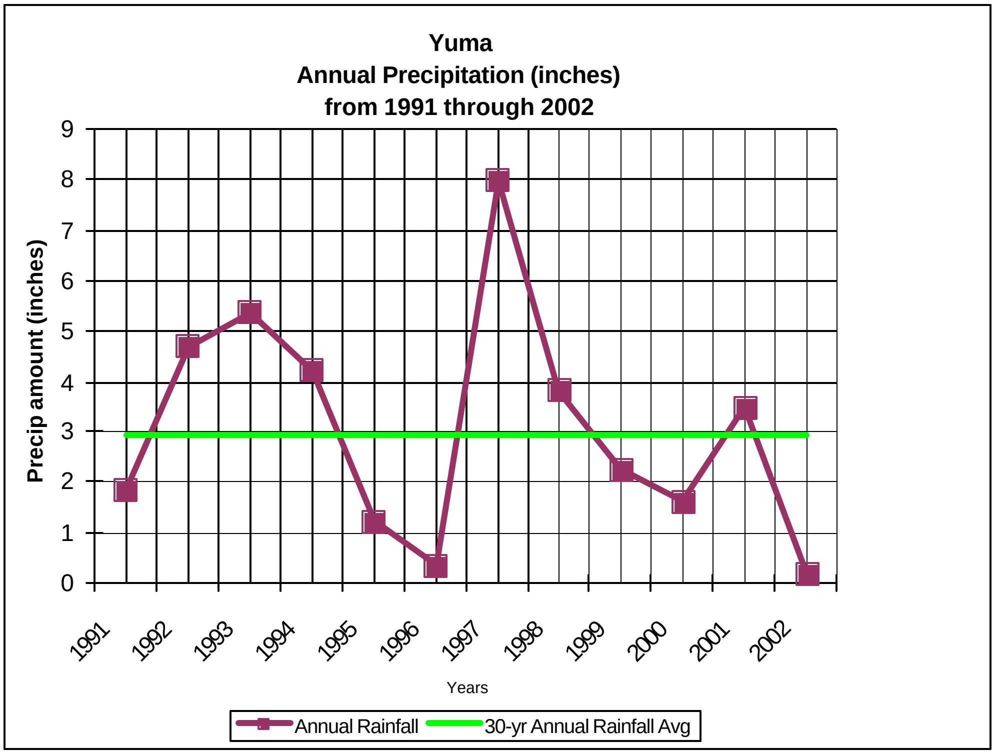
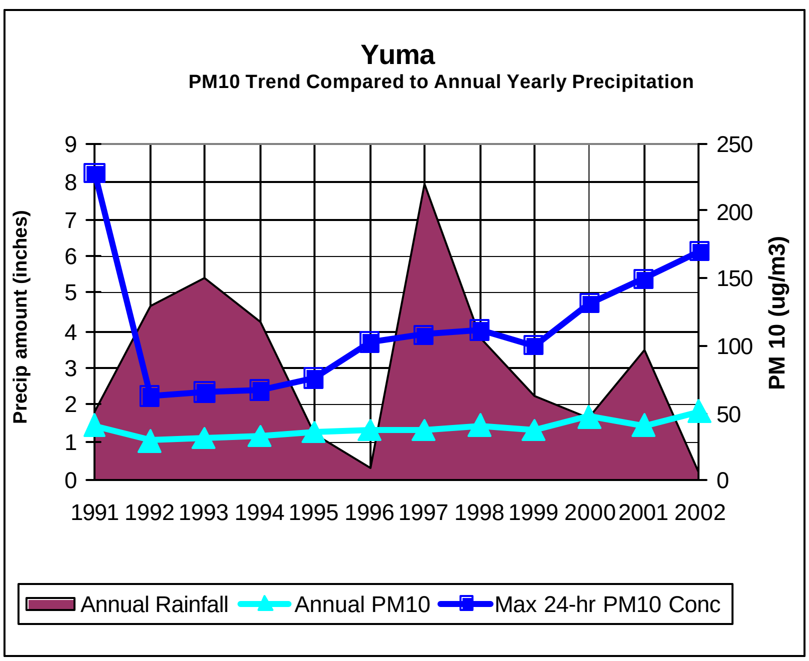


Figure 3-2 Yuma PM_{10} concentration trends with annual rainfall



4.0 WINDS AND PM_{10} CONCENTRATIONS ON AUGUST 18, 2002

4.1 Summary

Elevated concentrations of PM_{10}, measured in Yuma on August 18, 2002, were caused in part by extremely high and persistent winds associated with a major thunderstorm in Sonora, Mexico. The 24-hour average PM_{10} concentration in Yuma was 170 $\mu g/m^3$. The standard is 150 $\mu g/m^3$. Other monitoring sites in the vicinity showed elevated concentrations, some as high as 700 $\mu g/m^3$. Given the frequency of major dust storms in Yuma and the one-day-in-six sampling frequency, dust storms rarely produce violations of the PM_{10} standards. When this does occur, the Natural Events Policy (NEP) comes into play. The NEP requires local mitigation measures to be applied outside of the nonattainment planning requirements under Part D of Title I of the Clean Air Act.

4.2 Background

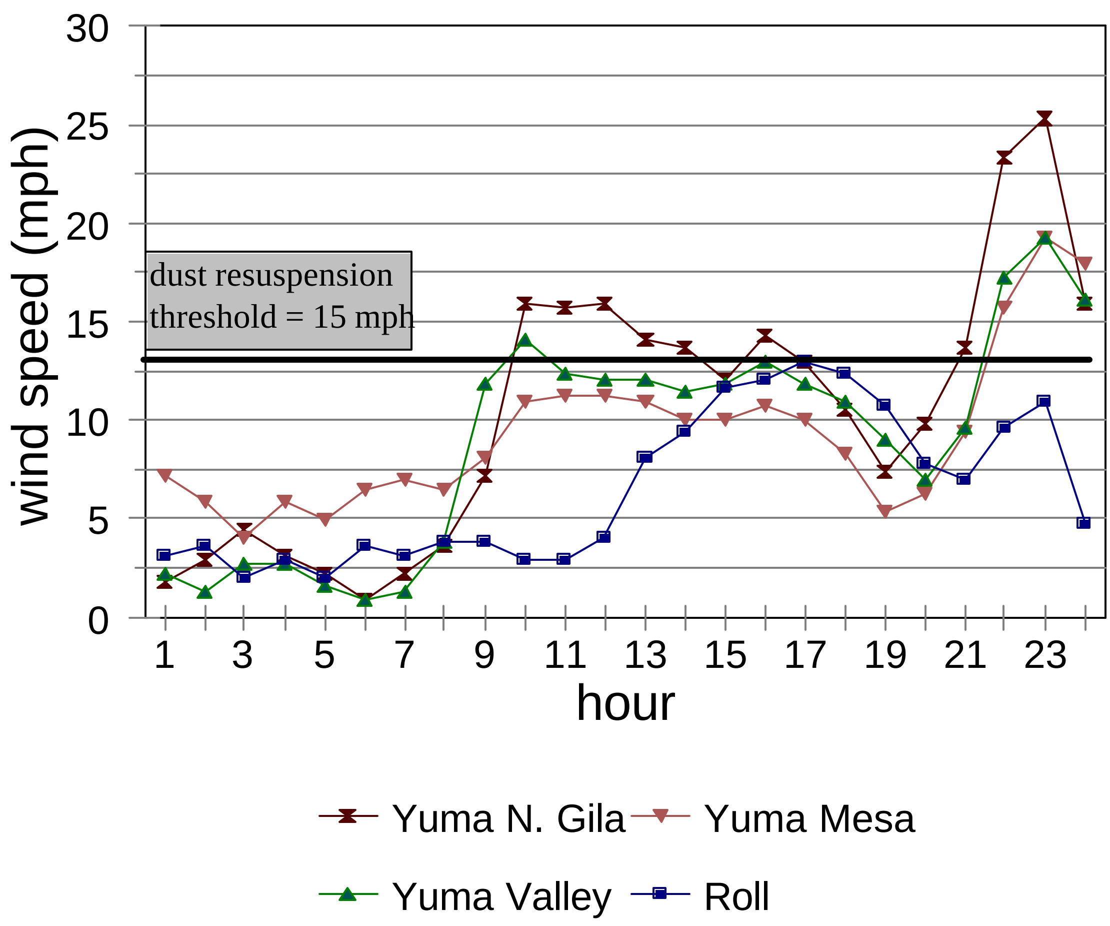
From 1985 through 2002, the highest 24-hour average PM_{10} concentrations in Yuma have exceeded the federal air quality standard of 150 $\mu g/m^3$ a total of nine times. This is a frequency of slightly less than one percent. The elevated concentration of 170 $\mu g/m^3$ recorded on August 18, 2002, is unusual, but not unprecedented.

The federal air quality standards for PM_{10} also include an annual average (which is 50 $\mu g/m^3$ averaged for three years). In the mid 1980s through 1990, Yuma exceeded this annual average standard and was declared a nonattainment area. A plan was carried out to reduce emissions of particulates. Since 1990, Yuma has been in compliance with this annual standard, and is now applying for redesignation to attainment through ADEQ. Although Yuma has exceeded the 150 $\mu g/m^3$ standard for the 24-hour NAAQS, it has not violated this standard since 1991.

4.3 Weather on August 18, 2002

During the early afternoon of August 18, 2002, large thunderstorms developed over western Chihuahua and eastern Sonora, Mexico in a moist and unstable air mass. These storms combined to form a Mesoscale Convective System (MCS), which continued to expand, intensify, and move towards the northwest. By 5:00 p.m. the entire southeast quarter of Arizona was under a cloud cover associated with this feature. At 9:30 p.m., the leading edge of a thunderstorm outflow boundary spawned by the MCS reached Yuma and produced sustained south-southeast winds of 37 mph with gusts to 44 mph. Visibility dropped rapidly from 10 miles to 1 mile in blowing sand and dust. Between 10:00 p.m. and midnight, visibility was at or below one mile and as low as 1/4 mile as south winds gusted near 40 mph. As is typical for a thunderstorm outflow boundary, barometric pressure rose rapidly and the air temperature fell, in this case 10 deg F. Restricted visibility (6 miles or less) was measured through 2:00 a.m. on August 19. The variation in wind speeds throughout the day can be seen in Figure 4-1. These data are taken from four sites in the Yuma area maintained by the University of Arizona. The locations of these meteorological sites, as well as three others that figure into this analysis in Section 5, are shown in Figure 4-3.

Figure 4-1 Hourly average wind speeds at four Yuma area sites on August 18, 2002

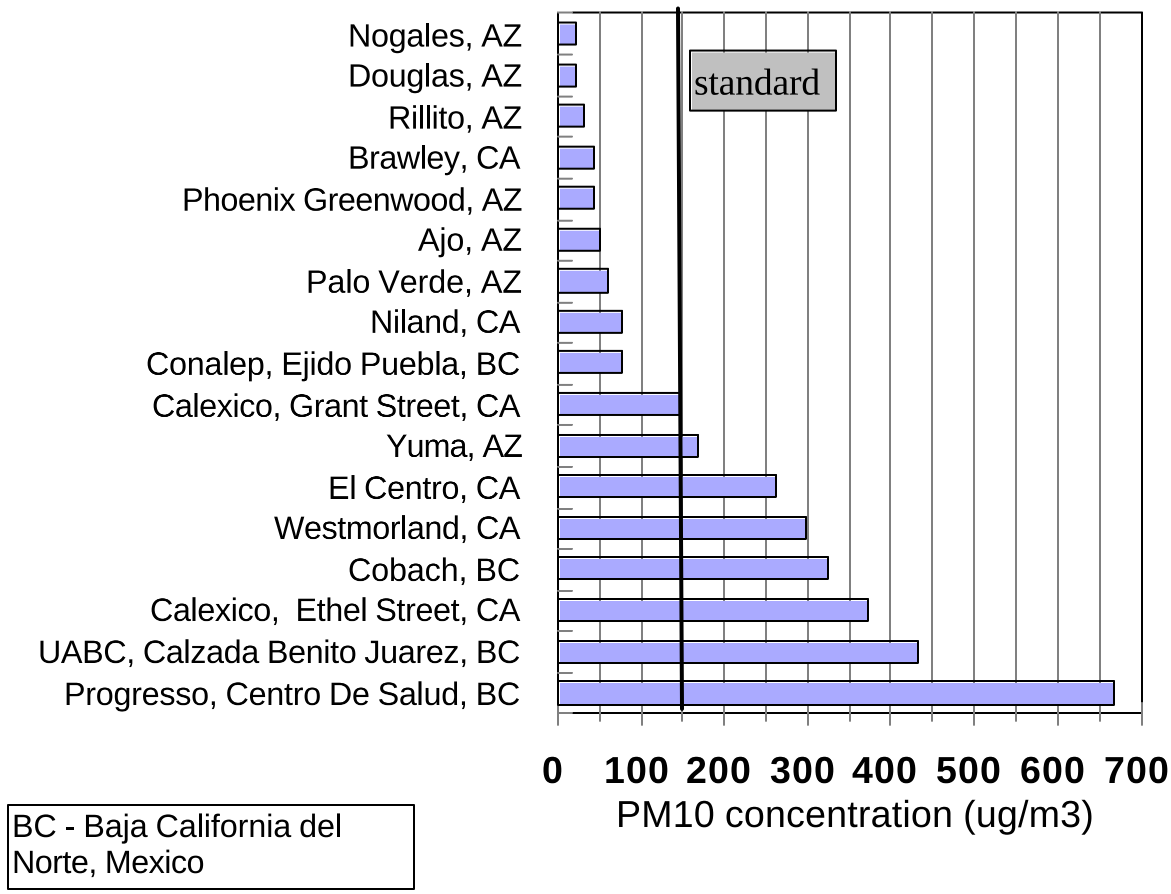


These data show that high winds with dust-producing potential were not limited to the late evening thunderstorm. In fact, 10 hours in the middle of the day had maximum wind speeds in excess of 15 miles per hour, the threshold wind speed to produce blowing dust. The highest wind speeds at the four sites were consistent with observations at the Yuma Marine Corps Air Station.

4.4 PM_{10} concentrations

PM_{10} monitoring networks are operated throughout Arizona, California, Sonora, and Baja California. Given the size and strength of this particular storm, and its generally northwestward movement from east-central Sonora towards Yuma, it is instructive to compare Yuma's PM_{10} concentration on August 18, 2002, with other sites. First, there were no elevated concentrations recorded in Arizona except in Yuma: Phoenix and the U.S. Mexico border concentrations were normal. Second, in the Imperial Valley, concentrations approached 300 $\mu g/m^3$. Third, monitoring sites in Baja California, near the border, recorded concentrations as high as almost 700 $\mu g/m^3$. The centerline of the storm, in its northwesterly course, appeared to have passed somewhat west of Yuma. Figure 4-2 presents these concentrations.

Figure 4-2 PM$_{10}$ concentrations (24-hour averages) in Yuma and surrounding areas on August 18, 2002



5.0 AUGUST 18, 2002, AS A NATURAL EXCEPTIONAL EVENT

5.1 Introduction

The Arizona Department of Environmental Quality is actively working to change the status of the Yuma airshed from nonattainment to attainment for PM_{10}. Until 2002, the last year that the 24-hour average PM_{10} standard was violated was 1991. This work consists of a modeling demonstration that air quality 10 years in the future will continue to meet the standards and that the most recent three years of PM_{10} concentrations meet the standards. Because insufficient samples were collected in 2001 to determine compliance with the standards, the Department will rely on the years 2002 through 2004, with a full PM_{10} maintenance plan to be submitted to the U. S. Environmental Protection Agency in 2005. In order to use the 2002 data, however, an exceedance of the PM_{10} standard on August 18 must first be analyzed through a Natural Events Action Plan (NEAP). The NEAP is designed to account for the influence of natural events such as wildfires and high winds on PM_{10} exceedances. Before such a plan can be carried out, ADEQ must establish a clear causal relationship between the measured exceedance and meteorological conditions that qualify as a natural exceptional event. The meteorological analyses described in this section show that August 18, 2002, qualifies as a natural exceptional event.

5.2 Natural exceptional event analysis

The objective of this analysis is to see whether the wind speeds and aridity associated with a PM_{10} exceedance are extreme enough to qualify the day as a natural exceptional event. There are several requirements for a date to qualify: including various air pollution monitoring requirements, a determination of the sources contributing to high PM_{10} concentrations, requirements to notify the U. S. Environmental Protection Agency, and meteorological tests to see if the winds are extreme and the conditions dry enough.

This section is concerned only with the meteorological tests, which are conducted to determine whether the exceedance date in question is considered meteorologically exceptional. These tests are described in an Arizona Department of Environmental Quality "Technical Criteria Document for Determination of Natural Exceptional Events for Particulate Matter Equal to or Less than Ten Microns in Aerodynamic Diameter (PM_{10})", May 31, 2000. This criteria document provides the technical basis defining natural exception events. The overall policy concerning these events is found in the "Air Quality Exceptional and Natural Events Policy", #0159.000, April 28, 1999, the State's regulatory basis of the Natural Events Action Plan.

Of the five meteorological tests, the first three concern wind speeds. The first test (Test #1), which is whether there were three or more hours with average wind speeds above the dust resuspension threshold, must be passed for the day to qualify as exceptional. The next two tests (#2 and #3) concern the 24-hour average wind speed. If test number 2 is passed, then the day qualifies. If the day fails test #2, then test #3 is performed.

Failing test number 3 eliminates the day. Passing it then requires that test numbers 4 and 5, concerning aridity, both be passed. As the following section explains, August 18, 2002, passes test number 1, fails number 2, and passes numbers 3, 4, and 5, thereby qualifying as a natural exceptional event.

Test #1: Did three or more hours during the exceedance have hourly average winds in excess of 15.7 miles per hour?
The University of Arizona's College of Agriculture operates four "AZMET" sites in the Yuma area (see Figure 5.1). One of these sites recorded six hours, two sites recorded three hours, and one site no hours of wind speeds at or above 15.7 miles per hour. These data, along with the official observations from the Yuma Marine Corps Air Station (MCAS), which had 11 hours of wind speeds 15.7 miles per hour or greater, are presented in Table 5-1, below. The date passes this test.

Figure 5-1. Yuma Area Meteorological Sites

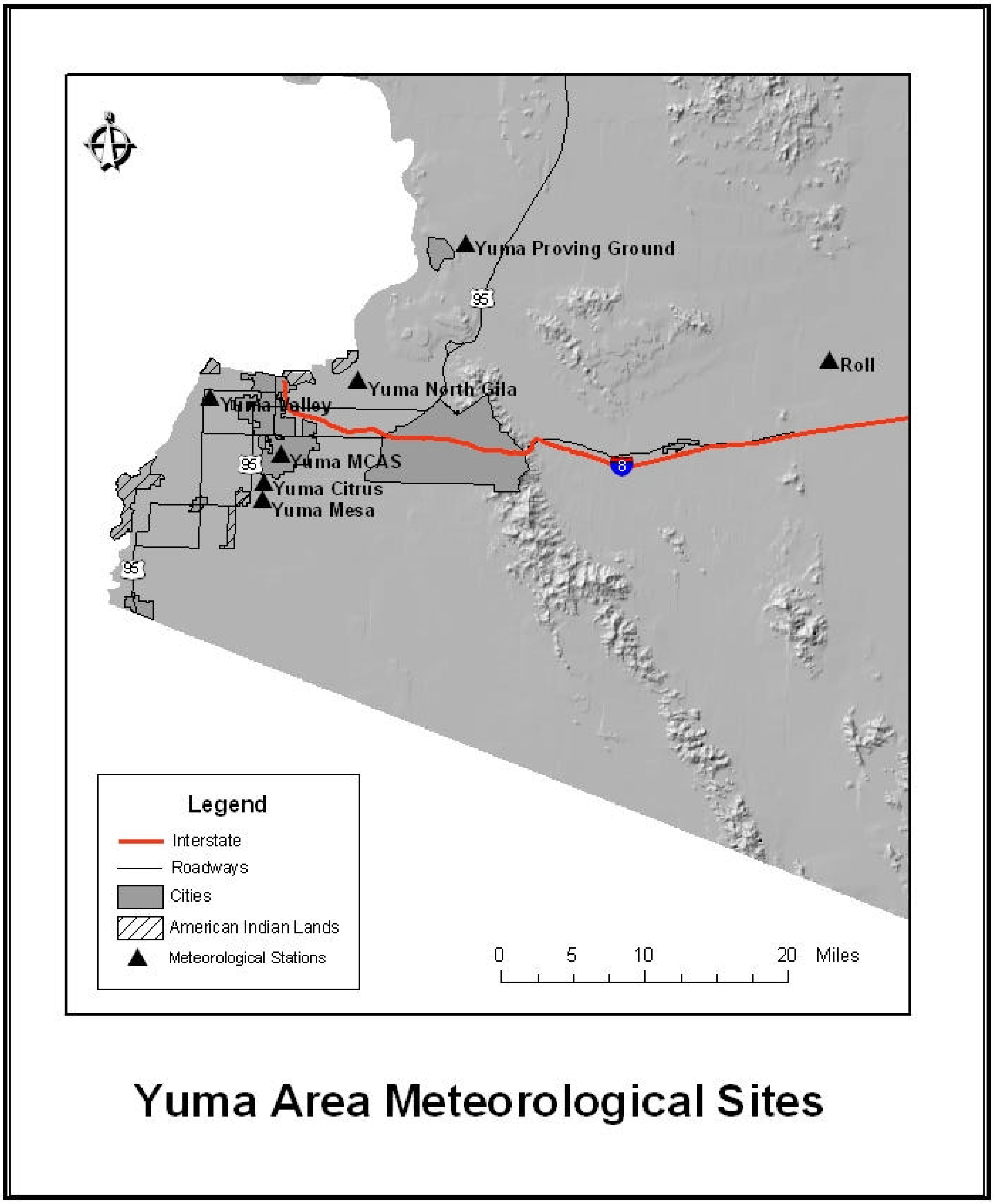


Table 5 -1. Hourly averaged wind speeds at five sites in Yuma on August 18, 2002

(speeds are in miles per hour)

Hour	N. Gila	Mesa	Valley	Roll	MCAS
1	1.8	7.2	2.2	3.1	10.4
2	2.9	5.8	1.3	3.6	10.4
3	4.5	4.0	2.7	2.0	9.2
4	3.1	5.8	2.7	2.9	11.5
5	2.2	4.9	1.6	2.0	11.5
6	0.9	6.5	0.9	3.6	11.5
7	2.2	6.9	1.3	3.1	15.0
8	3.6	6.5	3.8	3.8	15.0
9	7.2	8.1	11.9	3.8	**16.1**
10	**15.9**	11.0	14.1	2.9	**16.1**
11	**15.7**	11.2	12.3	2.9	15.0
12	**15.9**	11.2	12.1	4.0	13.8
13	14.1	11.0	12.1	8.1	**16.1**
14	13.7	10.1	11.4	9.4	**17.3**
15	12.1	10.1	11.9	11.6	**16.1**
16	14.3	10.8	13.0	12.1	13.8
17	13.0	10.1	11.9	13.0	10.4
18	10.5	8.3	11.0	12.3	13.8
19	7.4	5.4	9.0	10.8	**18.4**
20	9.9	6.3	6.9	7.8	**36.9**
21	13.7	9.4	9.6	6.9	**25.3**
22	**23.3**	**15.7**	**17.2**	9.6	**28.8**
23	**25.3**	**19.3**	**19.3**	11.0	**24.2**
24	**15.9**	**17.9**	**16.1**	4.7	**31.1**
avg	10.38	9.31	9.02	6.47	**16.99**
99.9th percentile 24-hour average					18.6
97th percentile 24-hour average					13.4

Test #2: Was the 24-hour average wind speed equal to or greater than the 99.9th percentile level? This level for Yuma is 8.3 meters per second, or 18.6 miles per hour. None of the average speeds are this high. The date fails this test.

Test #3: Was the 24-hour average wind speed equal to or greater than the 97th percentile level? This level for Yuma is 6.0 meters per second, or 13.4 miles per hour. The official observations at the MCAS show an average speed of 17 miles per hour. The date passes this test. Note, the MCAS observations are taken at 10 meters; the AZMET observations, at three meters. Wind speeds increase with the height above the ground, explaining some of the differences.

Tests 4 and 5 pertain to those dates which pass the third test.

Test #4: Was the precipitation in the 60 days preceding the exceedance less than the 4th percentile value? This level for Yuma is 0.0; Yuma recorded no precipitation between June 18 and August 18, 2002. Since the measured value of zero equals the 4th percentile of zero, the date has to qualify, even though it is not "lower than the 4th percentile value." The date passes this test.

Test #5: Was the precipitation in the preceding October – March period less than the 4th percentile level? This 4th percentile level is 0.28 inches, based on the Yuma Citrus station. The rainfall at the Yuma Mesa station for October 2001 through March 2002 was 0.15 inches, less than the 4th percentile value. The date passes this test.

Therefore, the August 18, 2002, date passes the criteria for a natural exceptional event, and qualifies for treatment through a Natural Events Action Plan.

Having examined the event, the next step is to determine the emission sources that contributed to the PM_{10} exceedance. This determination required an inventory of emissions, the subject of the next chapter.

6.0 EMISSIONS INVENTORY

6.1 Introduction

Thus far the discussions in this technical support document have been directed towards the weather on August 18, 2002, and the nature of PM_{10} air pollution itself. In this section, the inventory of emissions that contributed to the exceedances of the PM_{10} NAAQS will be briefly described. It appears in its entirety as the Appendix. Developed as part of the Yuma PM_{10} Maintenance Plan, the inventory is for 1999 and 2016. The suitability of this inventory for the August 2002 exceedance is discussed in Section 7, page 23.

In constructing such an inventory, one first makes an estimate of each important emission-causing activity. Examples include the number of vehicle miles driven on unpaved roads and number of acres of cotton tilled. EPA manuals and peer-reviewed literature are used to obtain emission factors. An example of an emission factor is the amount of PM_{10} pollution generated by each vehicle mile traveled on an unpaved road. The activity level is multiplied by the emission factor to produce the mass of emissions.

The summary table of emissions (Table 6-1) from the inventory report and the definitions of terms that will appear in the next section are given below. The definitions apply to the 33 subcategories of emissions, while the summary table has combined many of these.

Table 6-1
Yuma PM_{10} Nonattainment Area Emissions Summary - 1999

	Annual Emissions (tons)
Agricultural and Prescribed Burning	**40.7**
Agricultural Tilling	**3,572**
Agricultural Cultivation and Harvesting	**15.7**
Windblown Dust	**130,331**
Unpaved Roads - Re-entrained Dust	**10,183**
Paved Roads	**3,419**
Road Construction	**6,761**
General Building Construction	**53.8**
Aircraft	**15.5**
Unpaved Airstrips	**1.0**
Stationary Sources	**77**
Railroad Locomotives	**17**
Total	**154,487**

6.2 Definitions of PM_{10} Emission Inventory Categories

Each of the categories from Table 6-1 is defined below. Several of the categories have been subdivided and a separate definition is given for each subcategory.

Agricultural and Prescribed Burning

Emissions from the burning of citrus wood from commercial groves, whether from thinning or retirement of groves.

Agricultural Tilling

Agricultural tilling is defined as emissions from agricultural operations. The emissions in this category originate from agricultural tilling (land preparation, planting, weed control), and agricultural equipment exhaust.

Agricultural Cultivation and Harvesting

Agricultural cultivation and harvesting is defined as the emissions from these agricultural operations. The emissions in this category originate from cultivating and harvesting, as well as agricultural equipment exhaust.

Windblown Dust

Windblown dust comes from wind erosion, which is defined as the transport of disturbed or unconsolidated soil due to the movement of wind.

Windblown Dust– Agricultural Fields

Agricultural land is defined as agricultural fields for growing crops. The emissions in this category originate from wind erosion of disturbed topsoil from agricultural fields in the time period between harvesting and when a crop is tall enough to act as a windbreak .

Windblown Dust – Alluvial Channels

Alluvial channels are defined as geological features such as dry stream beds, arroyos, and gullies that are dry most of the year and contain loose soil, especially silt, due to water and wind erosion. The emissions in this category originate from wind erosion of material in the alluvial channel.

Windblown Dust – Miscellaneous Disturbed Areas

Cleared areas outside of the Yuma urbanized area consist of vacant lots and miscellaneous disturbed areas. Vacant lots are defined as undeveloped land with disturbed topsoil that are in residential or business area and miscellaneous disturbed areas are defined as areas with disturbed topsoil that do not fall into the previously mentioned emission categories. The emissions in this category originate from wind erosion of disturbed topsoil.

Windblown Dust – Unpaved Roads

The emissions in this category originate from wind erosion of disturbed topsoil of unpaved roads.

Windblown Dust – Urban Disturbed Areas

Cleared areas within the urbanized portion of Yuma are vacant lots and miscellaneous disturbed areas. Vacant lots are defined as undeveloped land with disturbed topsoil that are in residential or business area and miscellaneous disturbed areas are defined as areas with disturbed topsoil that do not fall into the previously mentioned emission categories. The emissions in this category originate from wind erosion of disturbed topsoil.

Unpaved Roads-Re-entrained Dust

Vehicular traffic on unpaved roads generates dust emissions: these roads are throughout the Yuma area.

Paved Roads

On-road Vehicles – Principal Arterials

On-road vehicles – principal arterials refers to vehicular emissions from major urban paved roads, many of which are located at one-mile intervals. The emissions in this category originate from brake wear, tire wear, exhaust, and road dust reentrainment (road dust “kicked back” into the air from vehicles driving over it).

Collectors – Yuma County

Collectors are paved roads that carry less traffic than arterials, and generally serve neighborhoods. These roads are typically at ¼ or ½ mile intervals. The term in this emissions inventory refers to same kind of vehicular emissions described above.

On-road Vehicles – Urban Collectors

Urban collectors are paved roads that carry less traffic than arterials, and generally serve neighborhoods within the urban portion of Yuma. These roads are typically at ¼ or ½ mile intervals. The term in this emissions inventory refers to same kind of vehicular emissions described in “on-road vehicles – principal arterials”

On-road Vehicles – Yuma County

Emissions from vehicular traffic on the lesser traveled paved roads of Yuma County

Road Construction

Emissions mostly from earthmoving but also exhaust from those projects on state (or federal) highways under the jurisdiction of the Arizona Department of Transportation, and the emissions from the construction of public roadways by the cities and County.

General Building Construction

Defined as construction of residential and commercial buildings, this term refers to emissions from earthmoving and to a lesser degree, construction equipment exhaust within Yuma County.

Aircraft

Aircraft – Yuma Marine Corps Air Station

Exhaust emissions from all aircraft -- including approach, taxi, takeoff, and climbout – comprise this category, which, in 1999, resulted from an average of 60 daily takeoff and landings.

Aircraft – Yuma International Airport

Exhaust emissions from all aircraft -- including approach, taxi, takeoff, and climbout – comprise this category, which, in 1999, resulted from an average of 25 daily takeoff and landings.

Aircraft – U. S. Border Patrol

Emissions from all aircraft -- including approach, taxi, takeoff, and climbout – comprise this category, which in 1999 resulted from an average of 2 takeoffs and landings per day.

Unpaved Airstrips

Dust emissions from aircraft landing and taking off on unpaved airstrips, and their exhaust emissions.

Stationary Sources

Miscellaneous Mining and Quarrying

Emissions from these activities originate from traffic on haul roads, materials excavation, and materials transport and handling.

Miscellaneous Manufacturing

Various manufacturing facilities of small to moderate size generate emissions through combustion, industrial processes, or materials handling.

Railroad Locomotives

Emissions from diesel locomotives, including switching, idling, and through traffic, are in this category.

7.0 AIR QUALITY MODELING

This section describes the air quality modeling performed to determine the contributing sources of the elevated PM_{10} concentration of August 18, 2002. The section begins with some necessary details about the emissions inventory and continues on to describe the numerical model that does the simulations. The section continues with a description of the meteorology, and finishes with some abbreviated results. The source category contributions are described in chapter 8.

7.1 Emissions Inventory

For modeling the August 18, 2002, exceedance, a March 31, 1999, emissions inventory was used with August 18, 2002, meteorological data. Pechan & Associates, Inc. had provided the emissions inventory in October 2002 to ADEQ, for use in the Industrial Source Complex Short Term V.3 (ISCST-3) modeling project. According to Pechan & Associates, Inc., the March inventory was suitable for the August date for the following reasons:

1. Winds on these two days are similar. On 3/31/99, there were 10 hours that exceeded the 15 mph threshold. Only one of these hours exceeded 20 mph. On August 18, the last 3 hours of the day exceeded the 15 mph threshold and no hours exceeded 20 mph. Hence, both days provided enough energy to generate windblown dust emissions fom surfaces prone to erosion (e.g. disturbed desert, vacant agricultural lands), but not enough to affect the more stable/lower silt surfaces (e.g. native desert and sand dunes).

2. Windblown dust emissions from agricultural fields are based, in part, on an assumption of 10% vacant agricultural lands in both spring and summer. This 10% figure applies equally to March and August. It is worth noting, however, that some of these fields will have been irrigated in preparation for planting.

3. There will probably be slightly less windblown dust from unpaved roads and disturbed urban area land uses in 2002 versus 1999 due to paving or other projects. However, these differences will be negligible in terms of overall emissions.

4. There will be slightly less agricultural land in 2002 versus 1999 due to urban encroachment. However, the differences will be negligible in terms of overall emissions.

For air quality modeling, the Yuma PM_{10} emissions inventory was distributed in grid cells of four by four kilometers. These grid cells comprised an emissions inventory and air quality modeling domain that included virtually all of Yuma, some of California, and some of Mexico. The emissions were also distributed among the hours of the day, so that those activities which take place in daylight only do not have nighttime emissions. It was this spatially gridded, hourly inventory of emissions that went into the air quality modeling work described in the remainder of this section.

7.2 ISCST-3 modeling

The source contribution modeling was done with the Industrial Source Complex Short Term V.3 model (ISCST-3). This model is a steady-state, Gaussian dispersion model that has been approved by the U.S. Environmental Protection Agency. For this application, the model was set up to predict PM_{10} concentrations for a 24-hour average, using urban dispersion and the area source algorithm, with the emissions set at ground level.

The modeling process required that the emissions inventory be split into separate files for each source category. This was done by loading the unified March 31st inventory file into a spreadsheet. In each new column, the emission rate for each source ID was listed, while zeroing out the source ID's that didn't apply. Separating the unified file in this manner provided 33 separate, but functionally identical, files for ISCST-3, and provided a simple means to quickly generate the needed files, without having to generate different input run streams for each model run.

After the separate emissions files were generated and the meteorological file was produced, one input run stream was built that could be used for each separate model run. An MSDOS batch file was also written to automate the modeling process, where the batch file executed the ISCST-3 model and systematically read each modeling scenario.

7.3 Meteorology

Meteorological data were acquired from four different Yuma, Arizona sampling sites, and organized according to the ISCST-3 modeling format, i.e., wind speed, wind direction, temperature, stability class, and mixing height. Each file was then examined to choose the most appropriate meteorological data for modeling. First, the meteorological file needed to meet the criteria of an exceptional event; and, second, it needed to be ISCST-3 "friendly".

Due to the model's tendency to over-predict and the large uncertainties in windblown dust emission factors, the ideal meteorological file for the ISCST-3 model would be one with the fewest sustained wind speeds at or near the accepted entrainment threshold of 15 miles per hour, averaged over one hour. Having fewer high-wind hours would limit the number of windblown dust hours input into the model, thus providing lower and more accurate overall predicted concentrations. The Yuma Mesa monitoring site was chosen for this modeling. Although it had high gusting winds for seven hours, only three of those hours had sustained winds above 15 miles per hour.

Table 7-1 shows the meteorological input file used for this scenario. The wind speed reflects the average wind speed over the hour and exceeds the accepted entrainment threshold for the final three hours.

Table 7-1 Meteorological data for August 18, 2002, Yuma dispersion modeling

	Wind Direction*	Wind Speed	Temperature	Stability Class	Mixing Height**
Hour	Flow Vector (deg.)	Miles/Hour	Fahrenheit	1=unstable - 6=stable	Meters
01	312	7.2	83.7	5	1100
02	310	5.8	82.6	5	1100
03	310	4.0	80.6	5	1100
04	302	5.8	81.0	5	1100
05	299	4.9	80.6	5	1100
06	304	6.5	79.3	5	1250
07	300	6.9	80.1	4	1250
08	305	6.5	83.1	4	1350
09	314	8.1	87.4	3	1500
10	320	11.0	90.7	2	1000
11	327	11.2	93.7	2	1500
12	329	11.2	97.7	2	2000
13	329	11.0	100.2	2	2000
14	334	10.1	102.0	1	2000
15	336	10.1	102.7	1	2000
16	334	10.7	102.6	1	2000
17	344	10.1	102.2	1	2000
18	348	8.3	100.8	1	2000
19	342	5.4	97.3	1	2000
20	318	6.3	91.6	1	2000
21	317	9.4	90.7	1	1000
22	323	**15.7**	88.0	1	1500
23	333	**19.2**	86.7	1	1250
24	334	**17.9**	85.5	1	1200

* Wind direction – the flow vector in compass degrees is the direction toward which the wind is blowing, e.g. at hour 1, 312 degrees means the wind is blowing towards the northwest.

** Mixing height is that height above the ground to which emissions released near ground level will readily rise.

Bold values: wind speeds in excess of the dust reentrainment threshold (15 mph)

7.4 Results

The model-predicted PM_{10} concentrations were examined for the Yuma Juvenile Center, the actual monitoring site. The predicted concentrations for the 24-hour average were unrealistically high, principally because of the uncertainty in estimating windblown emissions, but also because of the uncertainty of simulating the emissions with a dispersion model. In this type of modeling, the windblown emissions are assigned equally throughout each hour whose average wind speed is greater than 15 miles per hour. The model-predicted PM_{10} concentration for August 18, 2002, was 419 $\mu g/m^3$ at the Juvenile Center, 2.5 times as high as the measured concentration of 170 $\mu g/m^3$. Therefore, windblown emissions were scaled downward to better align the predicted concentration with the measured air quality. This scaling applied to all windblown emission categories for the final three hours of the day. The scaling factor was 0.1, meaning that only 10% of the original windblown emissions were used. This scaling procedure was approved by both the U.S. EPA's Region 9 and Office of Air Quality Planning and Standards. With this scaling, a concentration of 85 $\mu g/m^3$ was simulated.

The scaling could have been done to make the predicted concentration at the monitor exactly equal to the measured concentration. This approach was rejected because at this level of emissions scaling, several receptors in other grids had predicted concentrations between 200 and 300 $\mu g/m^3$. To lower these concentrations closer to the expected maximum range of 150-200 $\mu g/m^3$, the 90% reduction of windblown emissions was employed, even though it meant that the model-predicted concentration at the monitor was half of the measured value. The general operating principle here was to better simulate the conditions throughout the Yuma area, not just at the monitor. Because the model is not being used in an absolute sense (for example, to predict attainment of a standard), this model prediction is adequate for its intended use, namely to determine the source category contributions to the PM_{10} exceedance.

8.0 CONTRIBUTING EMISSION SOURCES ON AUGUST 18, 2002

The major reason for constructing an emissions inventory and performing air quality modeling, at least when viewed in the context of a Natural Events Action Plan, is to determine which emission sources are the important contributors to the elevated PM_{10} concentration. The sources can then be considered for Best Available Control Technology, in an effort to mitigate future exceedances of the air quality standard. The sources within the inventory are divided into "windblown" and "human", the former referring to dust blown off and resuspended from various types of land surface; the later, to any human activity, such as tilling a field, driving a car, or moving earth. Throughout this discussion, the reader needs to understand that the "contributions" are from the emission sources to a model-predicted concentration of PM_{10}. Each contribution is the portion of the total predicted PM_{10} concentration that can be attributed to a specific emission source. These contributions differ from the percentage the sources comprise of the emissions inventory. The inventory covers the entire Yuma area. The source category contributions under consideration in this document are related to a specific point in Yuma (the monitoring site), and are heavily influenced by the emission sources that are nearby and by the direction of the wind.

First, the windblown and human contributions, given in Figure 8-1, show that windblown and human activity are roughly equal. This can be understood by realizing that 21 hours have only human activity emissions, and that three hours have emissions from wind and human activity. Second, the windblown dust consists of five categories, of which four are of roughly equal importance at the monitoring site (Table 8-1 and Figure 8-2).

Table 8-1 Windblown dust category contribution to the elevated PM_{10} concentration of August 18, 2002, in Yuma

	%
Windblown Dust - Ag. Fields	29.8
Windblown Dust - Misc. Disturbed Areas	26.9
Windblown Dust - Unpaved Roads	25.4
Windblown Dust - Urban Disturbed Areas	17.7
Windblown Dust - Alluvial Plains / Channels	0.2
Total	100.0

Figure 8-1 Source category contributions to the elevated PM_{10} concentration of August 18, 2002, in Yuma: windblown vs human activity

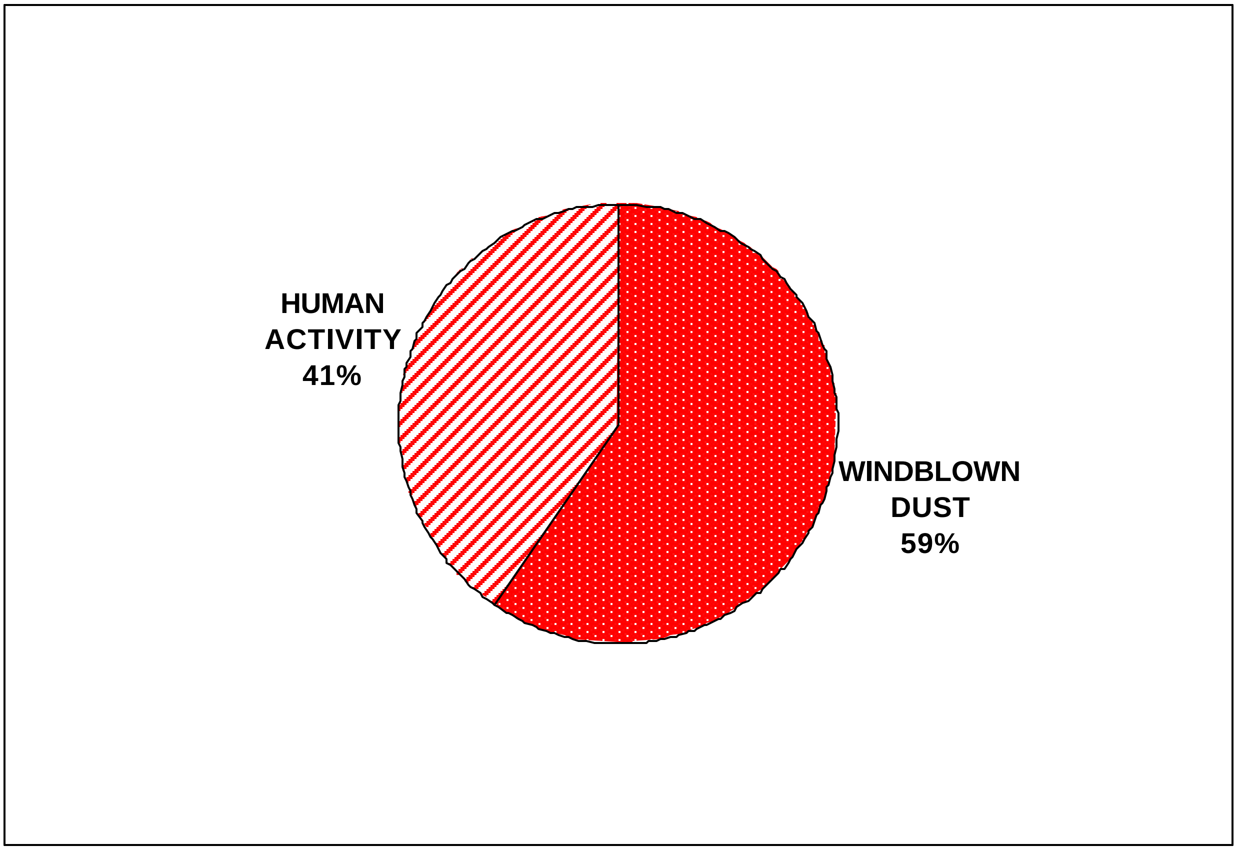
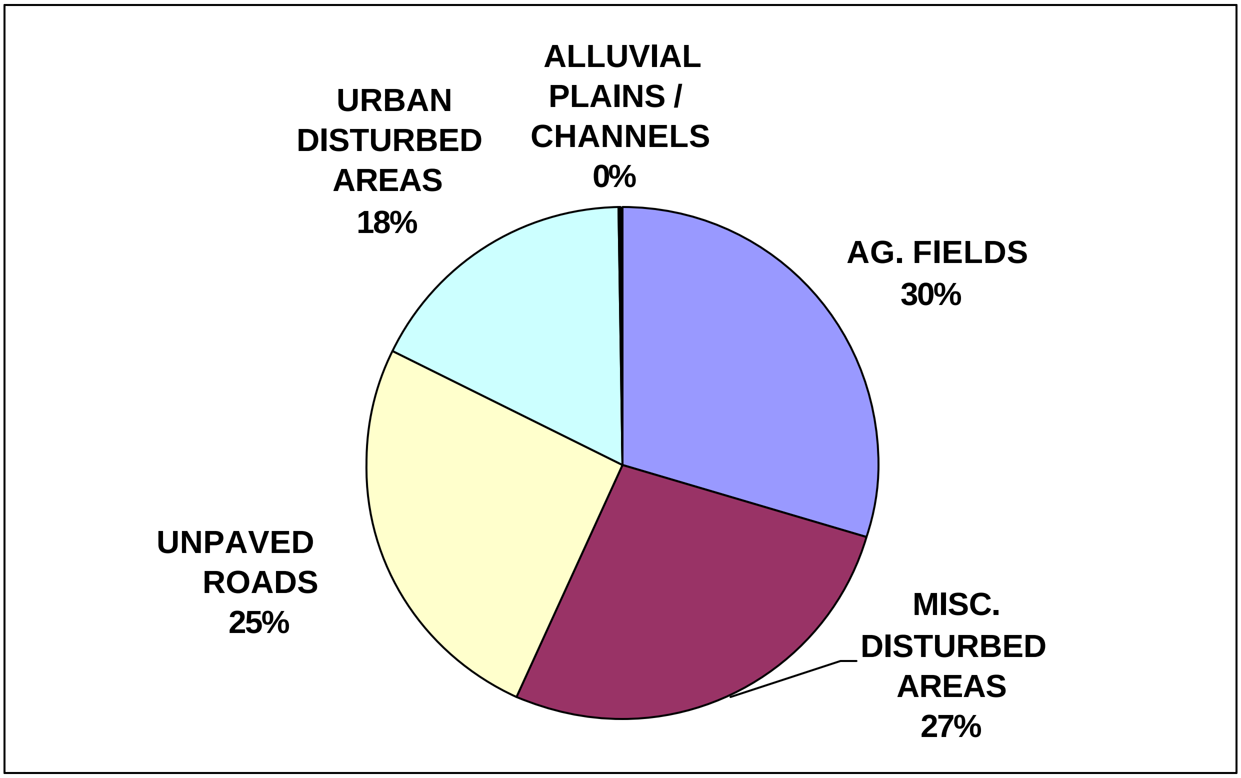


Figure 8-2 Windblown dust category contributions to the elevated PM_{10} concentration of August 18, 2002, in Yuma



This particular distribution of windblown contributions applies to the Yuma monitoring site at the Juvenile Center. Third, the human activity contributions can be broken down into their component parts. These contributions are given below in two tables. One is a summary (Table 8-2) of the other (Table 8-3), Figure 8-3 presents the data of Table 8-2.

Table 8-2 Human activity category contributions to the elevated PM_{10} concentration of August 18, 2002, in Yuma: a summary

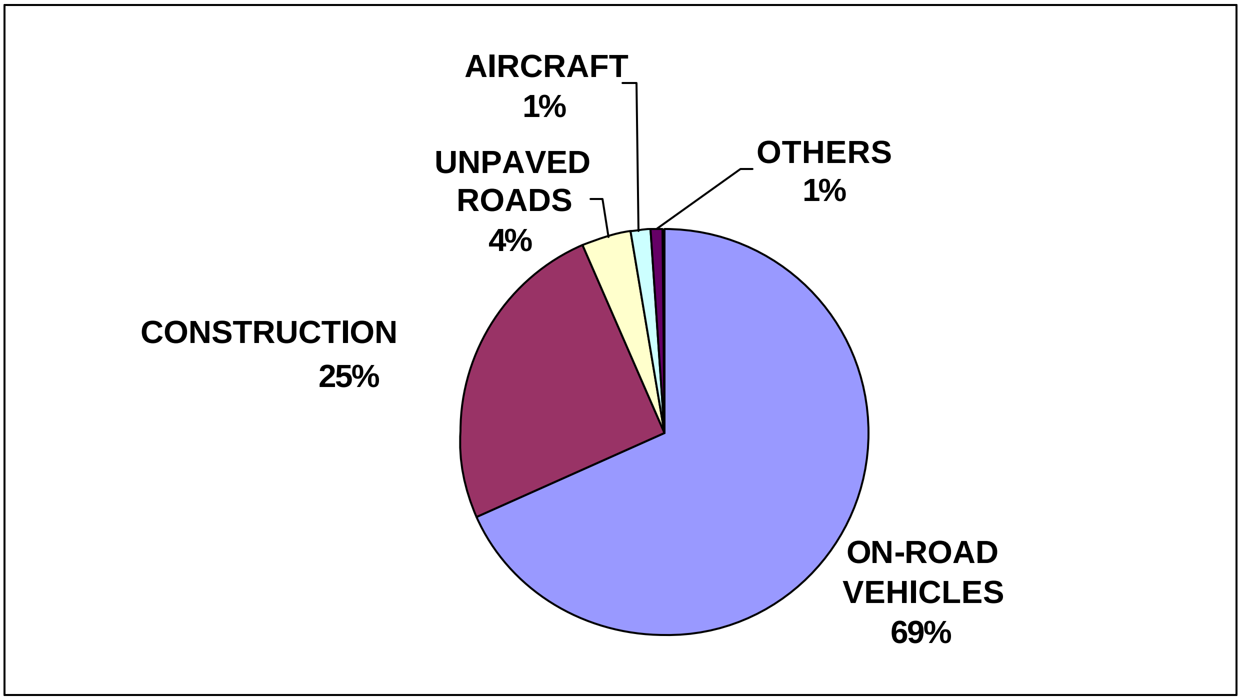
	%
On-Road Vehicles	68.20
Construction	25.39
Unpaved Roads	3.96
Aircraft	1.47
Others	0.98

Others: Misc. Mining / Quarrying, Misc Manufacturing, Railroads , And Ag. Burning – Citrus

Table 8-3 Human activity category contributions to the elevated PM_{10} concentration of August 18, 2002, in Yuma: details

	%
On-Road Vehicles - Principle Arterials	46.22
Collectors - Yuma County	19.35
Road Construction - City Of Yuma	13.23
Road Construction - Yuma County	9.24
Unpaved Roads	3.96
On-Road Vehicles - Urban Collectors	2.57
General Building Cons. - Yuma City	1.62
Aircraft - Yuma MCAS	1.01
General Building Cons.- Yuma County	1.01
Misc. Mining / Quarrying	0.58
Aircraft - Yuma International Airport	0.43
Misc Manufacturing	0.35
Road Construction - ADOT	0.29
On-Road Vehicles - Yuma County	0.06
Aircraft - Us Border Patrol	0.03
Railroads - Yuma County	0.03
Yuma County Ag. Burning - Citrus	0.03
National Defense	0.00
Aircraft - Yuma Proving Ground	0.00
Unpaved Airstrip - Pierce Aviation	0.00
General Building Cons. - Somerton	0.00
Yuco Cotton Gin - Yuma County	0.00
On-Road Vehicles - Other Mexico Paved Roads	0.00
Imperial Co. Harvest Ops./ Ag. Tilling/ Farm Eq.	0.00
Ag. - Food And Ag. Industrial Processes/ Boilers	0.00
Unpaved Roads - Imperial County	0.00
On-Road Vehicles - Imperial County	0.00
Railroads – Imperial County	0.00
Total	100.00

Figure 8-3 Human activity contributions to the elevated PM_{10} concentration of August 18, 2002, in Yuma



The causes of the elevated PM_{10} concentration of August 18, 2002, which is the focus of this Natural Events Action Plan, can be summarized as follows:

1. Windblown and human activity have roughly equal influence.

2. Four windblown components are about equal in their impact at the monitoring site: agricultural fields, miscellaneous disturbed areas, unpaved roads, and urban disturbed areas.

3. Human-generated emission categories most important in causing high PM_{10} are vehicular traffic on paved roads and construction.

As Best Available Control Measures are considered for Yuma, the most important emission sources to control are the four types of windblown dust, reentrained dust from vehicles on paved roads, and earthmoving dust from construction of roads, buildings, and homes.

9.0 CONCLUSIONS

- The PM_{10} exceedance on August 18, 2002, recorded at the Yuma Juvenile Center monitoring site, was 170 micrograms per cubic meter (μg/m^3), above the 24-hour average standard of 150 μg/m^3.

- A massive thunderstorm that originated in Mexico moved into the Yuma area on the afternoon of this date, bringing several hours of high, gusty winds and blowing dust.

- The high wind speeds on this date and the arid conditions that preceded it qualify August 18, 2002, as a natural exceptional event as defined in the Arizona Department of Environmental Quality Natural Events Action Plan policy.

- Through the construction of an emissions inventory and the application of an air quality dispersion model, the principal emission sources that contributed to this PM_{10} exceedance were:

  1. **Windblown dust – 59% of the total**
     a. Agricultural fields (30%)
     b. Miscellaneous disturbed areas (27%)
     c. Unpaved roads (25%)
     d. Urban disturbed areas (18%)

  2. **Human activities – 41% of the total**
     a. Reentrained dust from vehicles on paved roads (68%)
     b. Earthmoving activities associated with road and building construction (25%)
     c. Vehicles on unpaved roads (4%)

- The purpose of a Natural Events Action Plan is to reduce PM_{10} emissions from the principal sources that contributed to the exceedance to the extent practicable. The six most important sources are windblown dust from agricultural fields, from miscellaneous disturbed areas, from unpaved roads, and from urban disturbed areas; and reentrained dust from paved roads and earthmoving dust from construction activities. Regulatory efforts to reduce PM_{10} emissions in Yuma will need to focus on these six sources.